ARTHROSCOPIC REPAIR OF FULL-THICKNESS ROTATOR-CUFF TEARS: SURGICAL TECHNIQUE

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The indications and objectives for successful rotator-cuff repair are similar for open, mini-open, and all-arthroscopic techniques. The arthroscope should be considered only as a means to complete this procedure using less-invasive techniques. This technique is constantly evolving.

KEY WORDS: rotator cuff, arthroscopy, repair, technique

ANATOMY

The anatomy of the rotator cuff is important for intraoperative considerations regarding suture and anchor placement. The rotator cuff consists of 4 muscle-tendon units (supraspinatus, infraspinatus, subscapularis, and teres minor). The supraspinatus tendon inserts adjacent to the articular portion of the humeral head on the greater tuberosity posterior and lateral to the biceps tendon/coracohumeral ligament complex and 1-2 mm anterior to the bare area of the humeral head.[1] The bare area of the humerus is the insertion site of the infraspinatus tendon. This continues posterior to the inferior portion of the capsule where the teres minor inserts.[2] The subscapularis inserts on the lesser tuberosity as a diamond-shaped structure.

BIOMECHANICS

Tear pattern, anchor placement, suture type, and loop security are important factors in the success of repair. The successful rotator-cuff repair is the sum of these smaller parts and the goal is to maximize each part for successful overall repair.

Tear Pattern

Burkhart has broadly classified rotator-cuff tears into 2 basic patterns: crescent- and U-shaped tears[3] Crescent tears avulse from the bone but do not retract. U-shape tears extend much further medially to or beyond the glenoid. Theoretically, these may begin as L-shaped tears that lead to a U-shape tear under prolonged physiologic load.[4] Repair of the U-shaped tear often requires side-to-side suture placement (margin convergence) and anchor placement to repair the tendon to bone.

Anchor Placement

Suture anchors are the primary choice of fixation due to ease of insertion and data demonstrating sufficient strength during physiologic loading compared to transosseous tunnels.[5] The anchor should be placed at a 45° angle ("dead man's angle") in order to increase its resistance to pull-out.[6] Anchors are placed a minimum of 4-5 mm off the articular surface in a crescent configuration.

Suture Type

Mattress and simple sutures can both be used. The strength of simple sutures using #2 Ethibond (Ethicon, Johnson and Johnson, Norwood, MA) has been shown to be adequate for maximum loading conditions.[7] Prolonged absorbable sutures, as well as a newer suture containing a Kevlar core, are also being used (Arthrex, Naples, FL).

Arthroscopic Knots

There are 2 general knot categories: sliding and nonsliding. Sliding knots (Duncan loop, Tennessee slider, Roeder knot, Revo knot, Buntline hitch, etc.) rely on the ability of the suture to slide through the anchor and tissue. Nonsliding or basic half-hitch throws are based on internal friction and loop security.

Loop security refers to the ability to maintain a suture loop as the knot is tied. Knot security refers to the effectiveness of a given knot in resisting slippage or breakage when a load is applied. Knot security depends on 3 factors: friction, internal interference (the weave of the 2 sutures), and slack (removed by removing twists and past-pointing).[8] The loop is the limb that is weaved or unwrapped. The post is the suture limb that passes through the tissue and directs the knot to its destination.[9] Most knots fail by

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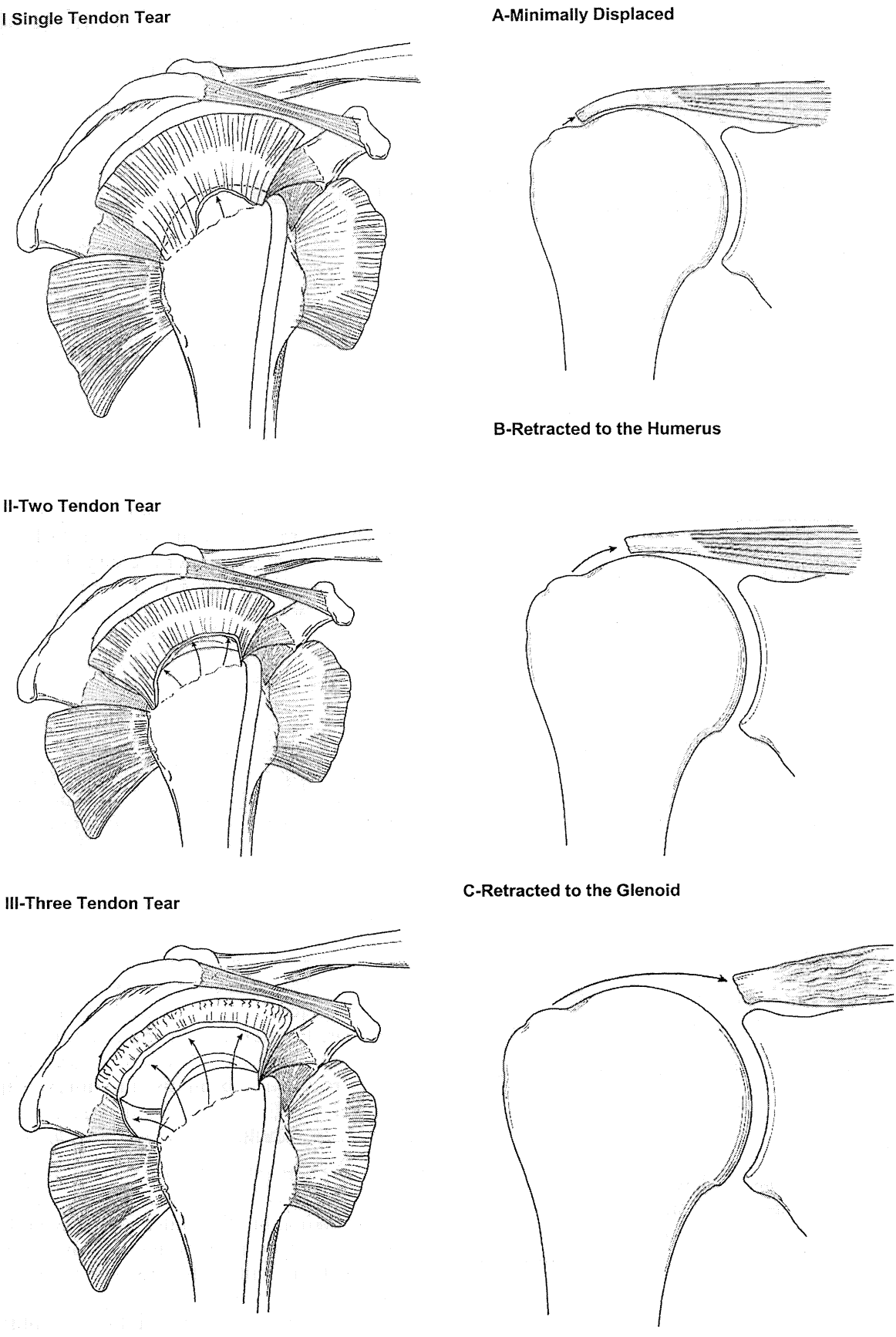

Fig 1. Classification of tears based on tendon involvement and amount of retraction.

rupture, so additional half hitches will not increase knot strength and will only add to the bulk of the knot configuration. The optimal configuration of a nonsliding knot is 2 half hitches on the same post and then 3 alternating half hitches on alternating posts.[9]

PERIOPERATIVE CONSIDERATIONS

Indications and contraindications for arthroscopic repair are generally identical to open repair. Inability to achieve secure arthroscopic repair suggests that one should per-

form open or mini-open rotator-cuff repair. Appropriate preoperative radiographs (true anterior to posterior, axillary, and supraspinatus outlet view) is obtained to evaluate acromial morphology, os acromanale, degenerative joint disease, superior migration of the humeral head, and acromioclavicular joint morphology.[12] The saggital and coronal oblique magnetic resonance imaging scan is used to assess muscle quality, which may have prognostic value. We classify tears based on tendon involvement and the amount of retraction: I = a single tendon tear; II = 2 tendons; III = 3 tendon tears; A = nondisplaced; B = displaced to the humerus; and C = displaced to the glenoid (Fig 1).

OPERATIVE TECHNIQUE

Preoperative Considerations

A combination of interscalene block and general anesthesia is preferred to minimize inhalation agents and provide postoperative pain relief.[13] Although lateral decubitus position can be used, the beach-chair position is preferred due to its familiar orientation, ease of setup, and conversion to an open procedure.

Portal Placement

The bony anatomy and 4 arthroscopic portals are outlined and injected (0.5% Bupivicaine). These 4 portals can be used to repair most rotator-cuff tears assisted by arm rotation. The *posterior portal* is generally made approximately 2 cm inferior and 2 cm medal to the posterior lateral corner of the acromion. The *lateral portal* is made in line with the posterior border of the clavicle and 2 cm from the edge of the acromion.

The *anterior portal* is generally just lateral and at the same level as the coracoid process in line with the anterior border of the AC joint. A fourth portal or *accessory anterolateral portal* is created about 5 mm off the anterolateral corner of the acromion; it is localized by using a spinal

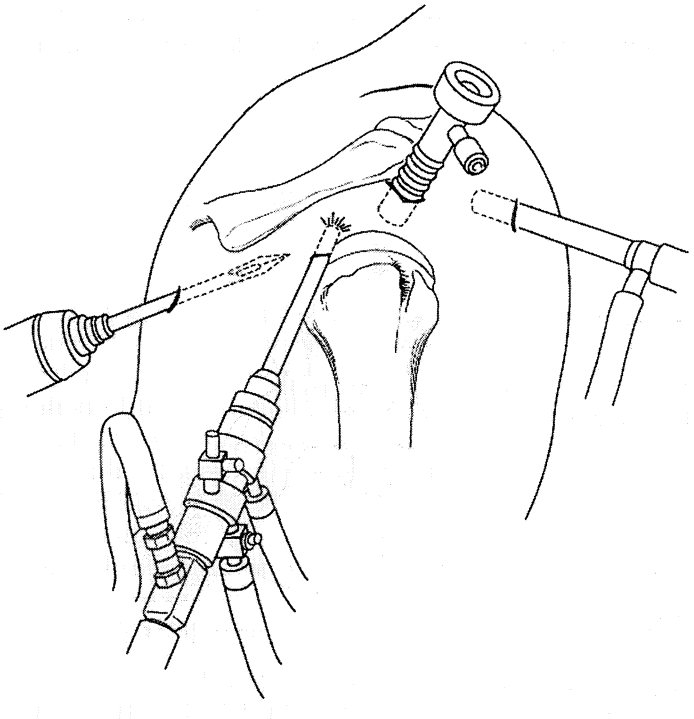

Fig 2. Right shoulder in a beach-chair position showing 4 portals. The posterior portals are instrumented with an arthroscopic penetrater. The lateral portal is instrumented with a camera and the inflow. The accessory anterior lateral portal has an Arthrex clear 6.0-mm cannula off the anterior lateral portion of the acromian. The anterior portal is instrumented with a standard anterior cannula that has the outflow connected to it.

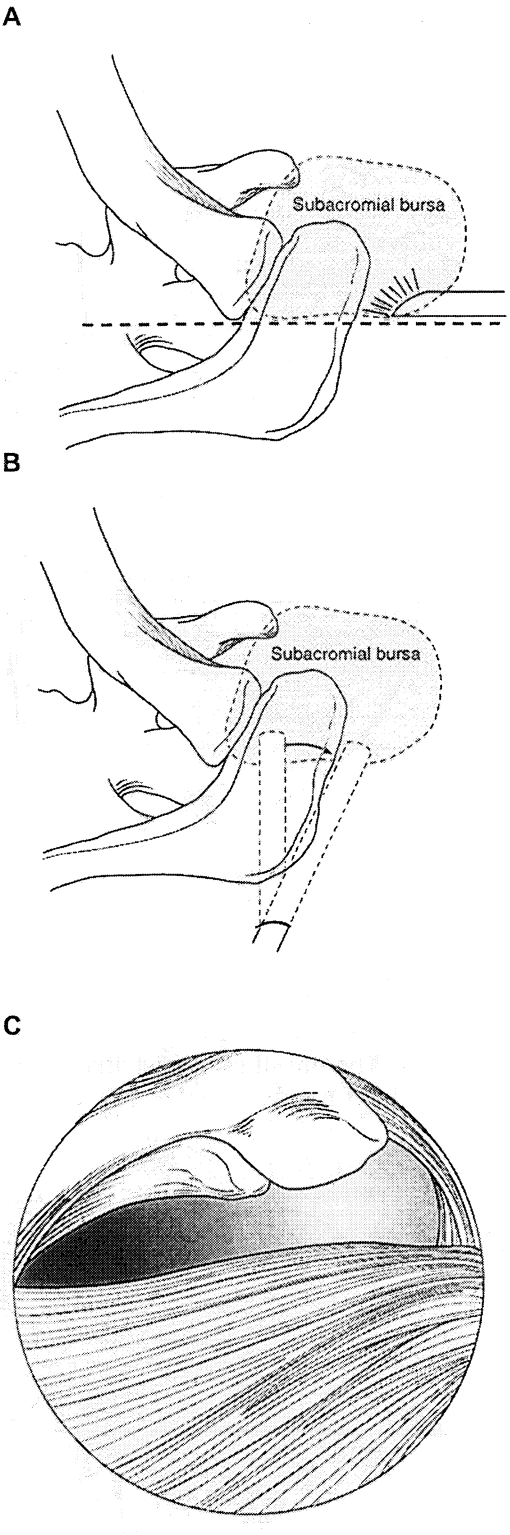

Fig 3. (A) Anatomical position of the Subacromial bursa; (B) technique for entrance to bursa; (C) "room with a view".

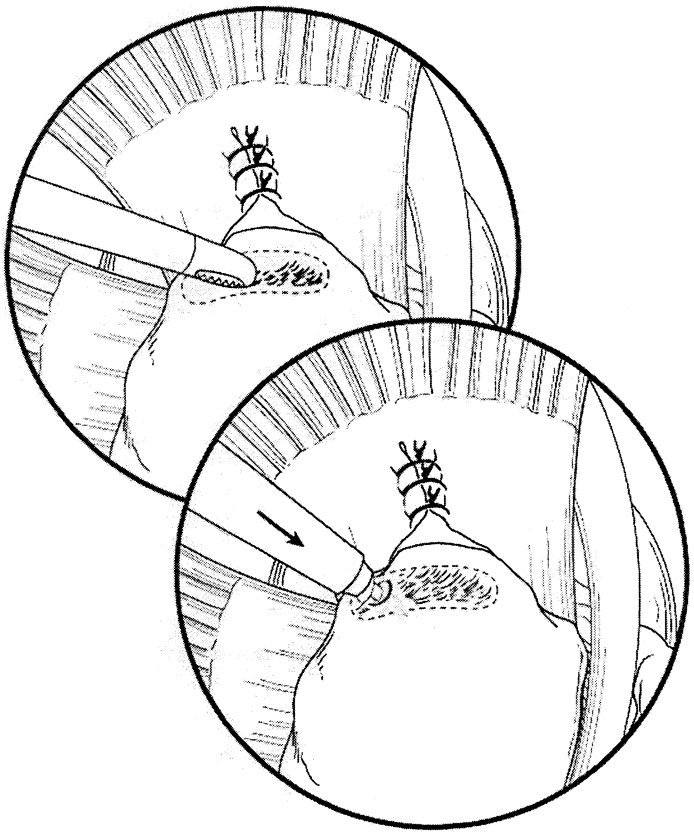

Fig 4. Arthroscopic preparation of greater tuberosity.

needle to confirm the appropriate angle for anchor insertion, assisted by arm rotation (Fig 2).

An arthroscopic pump is used to provide fluid control and hemostatsis. The anesthesiologist maintains the patient's systolic blood pressure between 100 and 110 mm Hg. Pump pressure is set at 35-40 mm Hg during glenohumeral arthroscopy, and only transiently increased to 40-60 mm Hg as needed while performing subacromial work.

Intraarticular Evaluation of the Rotator Cuff

Diagnostic arthroscopy is performed and the tear location is marked with a spinal needle. A #1 or #0 monofilament suture is passed through the spinal needle and retrieved through the anterior cannula and snapped to the suture limb exiting the skin. This technique aids in identifying the leading edge of the supraspinatus while working in the subacromial space. On entering the subacromial space, "a room with a view" is established by angling the blunt tocar medially and then placing it laterally to visualize the subacromial bursa (Fig 3). The lateral portal is instrumented with a shaver or an electrocautery ablation device to perform a complete bursectomy. In the absence of significant inflammation or with a relatively flat acromion, a decision may be made to avoid a formal subacromial decompression. To avoid axillary nerve injury, debridement of the bursal tissue in the lateral gutter should not proceed beyond the bursal reflection (3-5 cm).

Arm abduction provides access to the lateral gutter for visualization of the greater tuberosity. Forward elevation increases the space for working on anteriorly based supraspinatus tears. Arm adduction is important for anchor insertion. Internal and external rotation allow visualization of the entire tear and help to align sutures for arthroscopic knot tying. Gentle longitudinal traction improves the space available for instrumenting during repair.

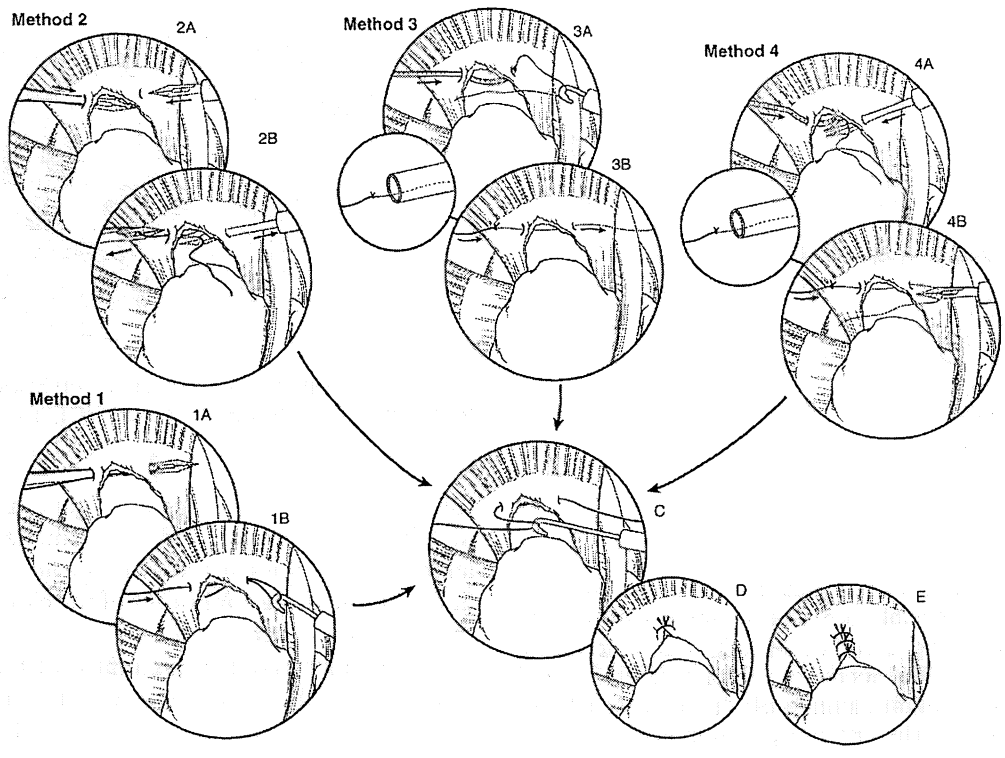

Fig 5. Four methods of margin convergence.

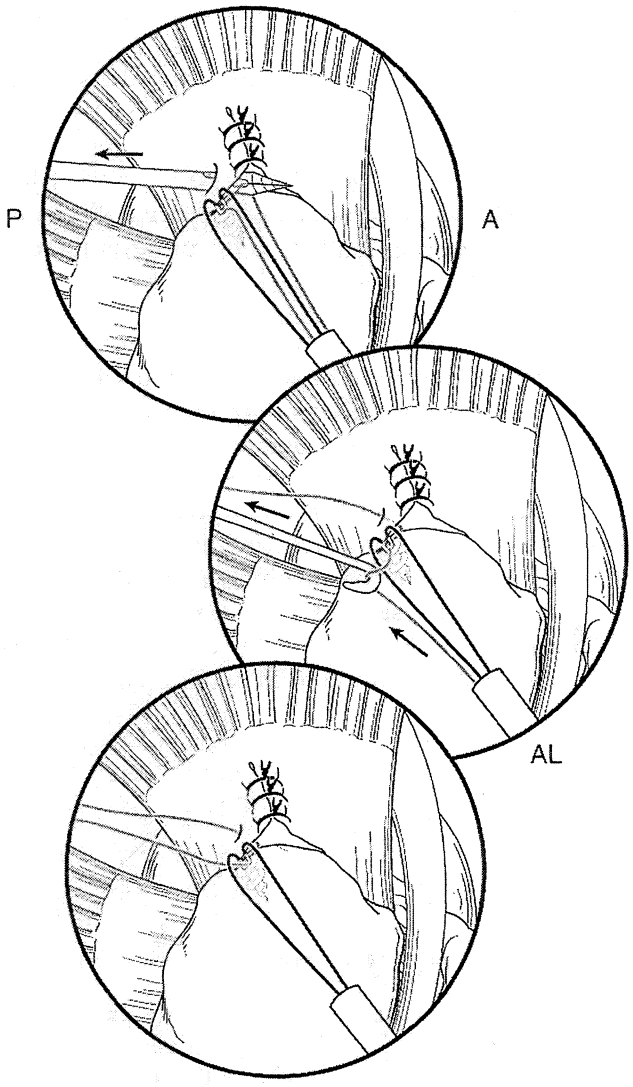

Fig 6. Posterior tendon leaf with penetrator.

Preparation for Tendon Repair

For the majority of the procedure, the arthroscope will remain in the lateral portal, providing a panoramic view of the tear and repair site. Tendon mobility is evaluated by grasping the tendon through the anterior or anterolateral portal and gently pulling it laterally. This determines the position of the tendon edge relative to the repair site on the tuberosity. Excursion can be increased, when necessary, with intra-articular capsular release above the labrum, excision of the fibrous adhesions on the bursal side of the rotator cuff, and release of the coracohumeral ligament and rotator interval.[14]

Tuberosity Preparation

The anatomic soft-tissue foot print on the greater tuberosity is superficially debrided with preservation of the cortex in order to maximize anchor pull-out strength. The tendon edge may also be conservatively debrided at this time, but the structural fibers of the tendon are preserved (Fig 4).

Arthoscopic Repair

After the subacromial decompression (if indicated), the tear pattern is identified. If a side-to-side component exists, margin convergence is performed by 1 of 4 methods in an effort to reduce the lateral tension of the final repair. The arthroscopic is maintained in the lateral portal and instrumentation is performed through the posterior or anterior portal. When using suture-passing devices, it is generally easiest to pass them percutaneously through the soft-tissue portal rather than a cannula due to size constraints and the need to maximize mobility within the subacromial space. Sutures are generally tied through the anterior or anterolateral portal and always through a cannula, and knots are placed on the posterior cuff in order to minimize knot irritation during forward elevation.

Side-to-side repair

METHOD 1. Antegrade Suture Passage: A soft-tissue penetrator loaded with a braided suture is passed through the posterior portal in order to penetrate both the posterior and then the anterior leaflet of the U-shape tear. A crochet hook passed through the anterior portal retrieves the suture limb from the penetrator and the trailing limb from

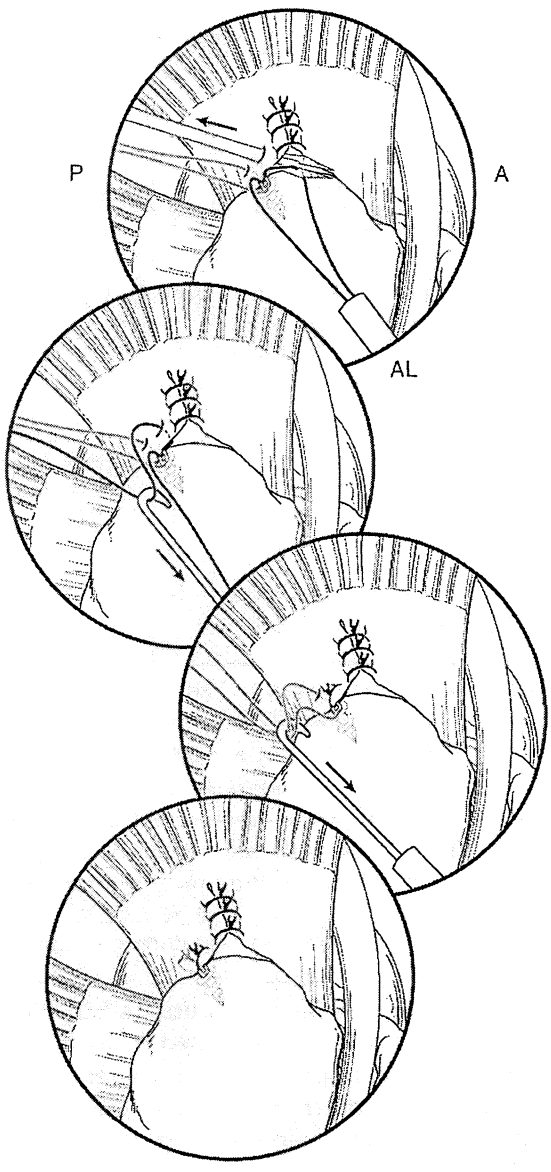

Fig 7. Securing posterior tendon leaf.

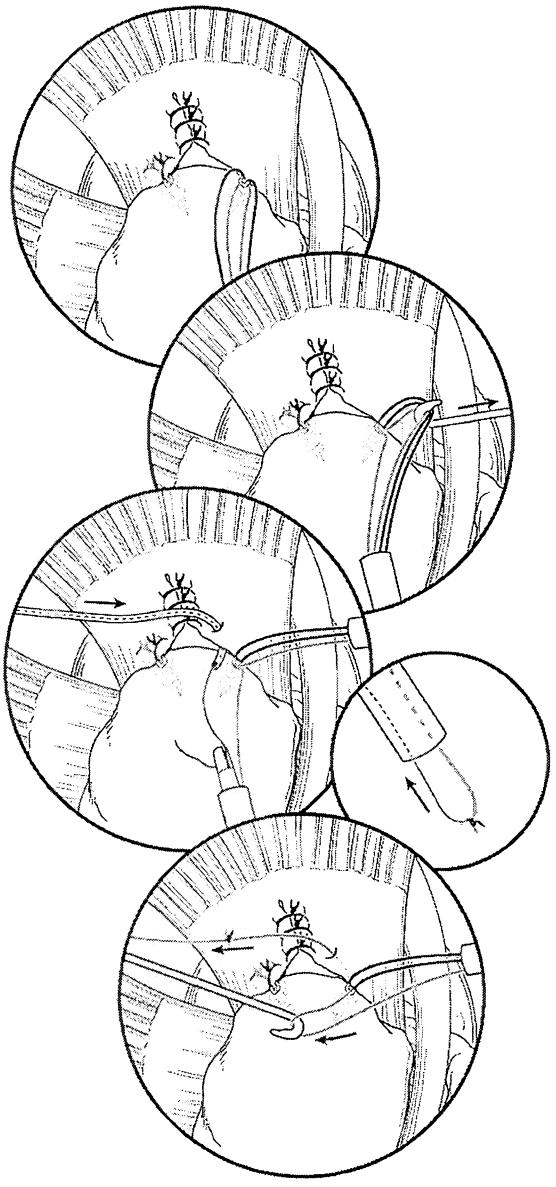

Fig 8. Anterior tendon leaf with suture passer from posterior portal.

the posterior leaflet. This suture is then tied in-line through the anterior portal (Fig 5).

METHOD 2. Antegrade Suture Hand-Off: A soft-tissue penetrator loaded with a braided suture is passed through the posterior portal in order to penetrate only the posterior leaflet, and a second penetrator is placed through the anterior portal and cuff leaflet to meet in the middle of the field of view. The suture is then dropped by the posterior penetrator and picked up by the anterior penetrator and pulled out the anterior portal. The remaining steps are similar to Method 1 (Fig 5).

METHOD 3. Retrograde Suture Shuttle: A Linvatec spectrum is (Linvatec, Largo, FL) loaded with a #0 or #1 monofilament suture. Depending on the angle of the tear, a 45° bend to the right or left or a straight "crescent" suture hook is passed through the posterior portal into the posterior leaf of the cuff and though the anterior leaf of the cuff. The monofilament suture is then advanced and retrieved through the anterior portal by the crochet hook. A permanent suture is then tied to the free monofilament suture end outside the anterior portal, and the spectrum and monofilament are withdrawn from the posterior portal. This effectively "shuttles" the permanent suture through both leaves of the rotator cuff. A crochet hook passed through the anterior portal retrieves the suture limb from the posterior leaflet. This suture is then tied in-line through the anterior portal (Fig 5).

METHOD 4. Retrograde Suture Shuttle Hand-Off: A Linvatec spectrum (Linvatec, Largo, FL) loaded with a #0 or #1 monofilament suture. Depending on the angle of the tear, a 45° bend to the right or left or a straight "crescent" suture hook is passed through the posterior portal into the posterior leaf of the cuff. A straight penetrator is placed through the anterior portal and the anterior leaf of the rotator cuff to retrieve the monofilament suture as it is advanced through the spectrum suture hook. The penetrator then retrieves the suture out the anterior portal. The remaining steps are identical to Method 3 (Fig 5).

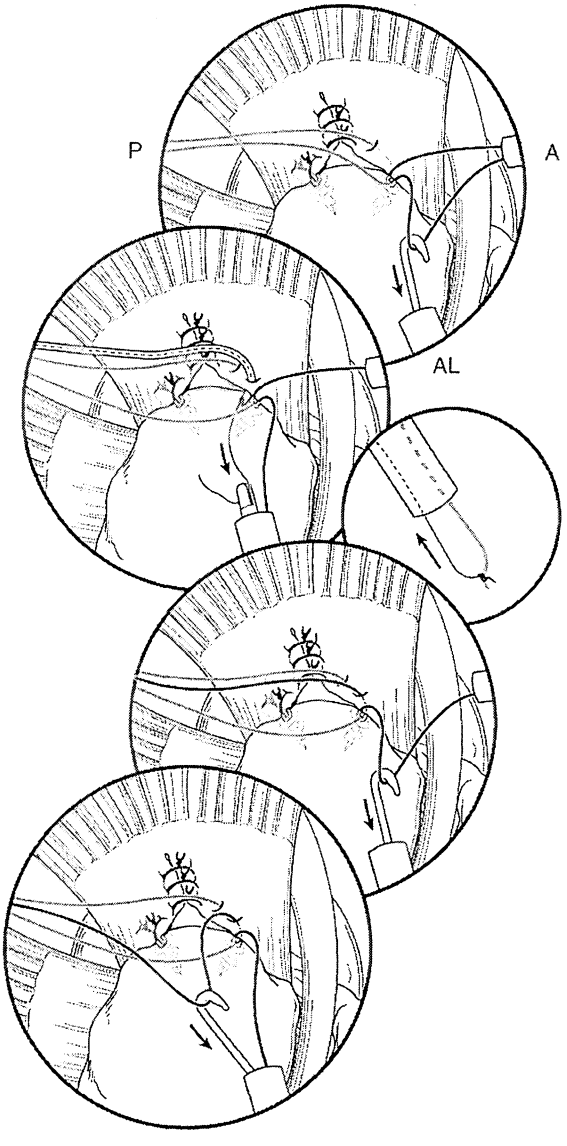

Fig 9. Anterior-tendon-leaf suture management.

Anchor Placement

Our preferred location for anchor placement is approximately 5-10 mm lateral to the articular surface of the humerus. Some surgeons, however, recommend anchor placement near the junction of the anatomic neck and greater tuberosity. The anchor should be inserted at a 45° angle to the vertical, the so-called "dead man's" angle, in order to maximize resistance to pull-out. Suture anchors that allow for 2 independent sutures per anchor through independent eyelets are ideally suited for rotator-cuff repair.

Proper anchor placement is facilitated by arm rotation and longitudinal traction. Suture anchors can be placed through the accessory anterolateral portal or percutaneously through additional small incision when necessary. The number of anchors used is based on the tear size. Separating each suture anchors by approximately 5-8 mm will proportionally distribute fixation over the entire insertion site and minimized excessive tension at any single fixation point. Anchors should be placed from posterior to anterior while tying sutures before subsequent anchor placement.

Posterior Leaf Repair to Tuberosity

After anchor insertion, a soft-tissue penetrating device is brought in from the posterior portal to pierce the posterior tendon no less than 5 mm from its leading edge in order to retrieve the most medial suture limb (of a single suture set) and pull it through the tendon and out the posterior portal. When inserting the penetrator, it is important to view its entrance into the subacromial space to prevent inadvertent penetration or damage to the infraspinatus muscle. A crochet hook is then brought through the posterior portal to retrieve its mate (Fig 6). This suture pair is clamped with a hemostat to maintain their identity during suture tying. This step is repeated slightly more anterior within the posterior cuff leaflet. The suture sets are serially retrieved and tied through the accessory anterolateral portal (Fig 7). Additional anchors and sutures are placed as necessary.

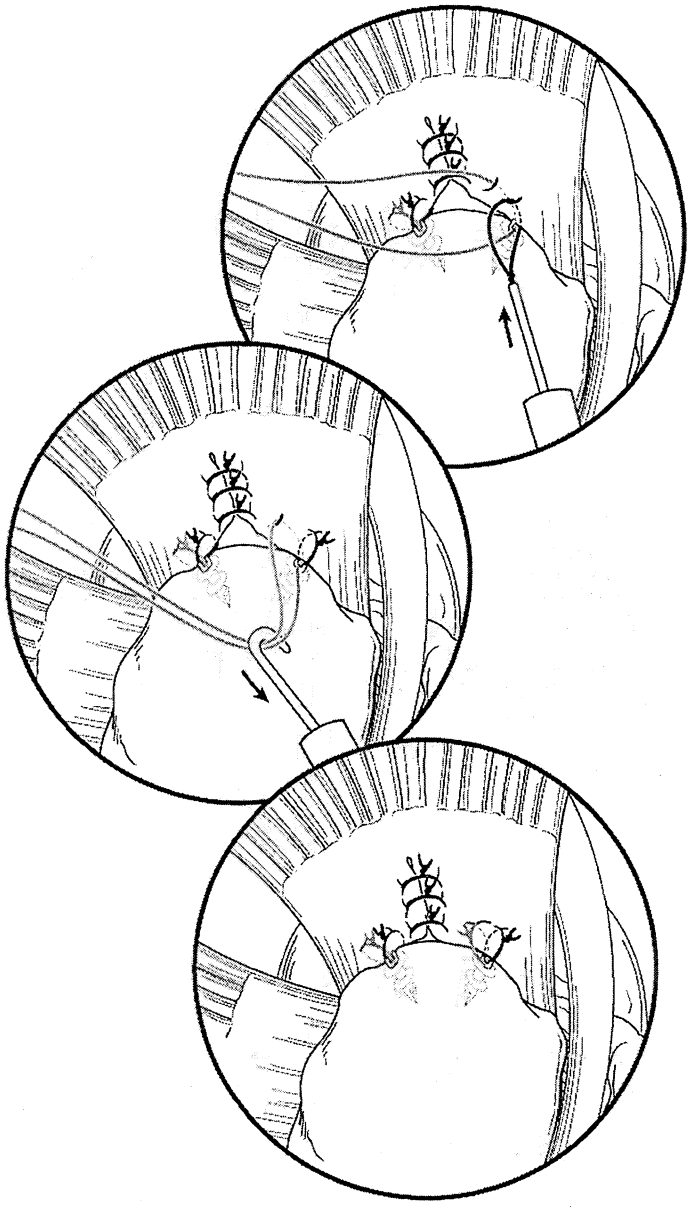

Fig 10. Securing of anterior tendon leaf.

Anterior Leaf Repair to Tuberosity

Two techniques are presented in this section with the anchor placed through the anterolateral portal, as described previously. One technique involves instrumenting from the posterior portal; the other technique involves instrumenting through the anterior portal.

The first technique involves using a crochet hook to retrieve 3 of the 4 sutures from the anterolateral portal and bring them out through the anterior portal, leaving a single medial limb of a suture within the anterolateral cannula. A Linvatec spectrum device is then placed through the posterior portal (in this case a 45° bend to the right for a right shoulder) and passed through the anterior leaf of the tendon. An arthroscopic gasper is used through the anterolateral portal to retrieve the monofilament suture, which is tied around the permanent suture limb remaining in the anterolateral portal. This permanent suture is then shuttled through the tissue as the spectrum and monofilament are withdrawn from posteriorly. A crochet hook passed through the posterior portal retrieves the second limb (its mate) and these are then held together with a hemostat (Fig 8). The steps are repeated for the second suture after retrieving the most medial suture limb from the anterior cannula through the anterolateral cannula (Fig 9). Sequential knots are then tied through the anterolateral portal from anterior to posterior, thus securing the anterior leaf of the rotator cuff (Fig 10).

The second technique involves retrieving 3 of the 4 sutures from the anchor and placing them out the posterior portal. A suture-passing device is placed in the anterior portal to penetrate the anterior leaf of the cuff. A crochet hook placed through the anterolateral portal retrieves the loop of suture and shuttles it through the tissue. This limb is left in the anterior portal (Fig 11). The crochet hook then retrieves a single limb from the second pair of sutures out the anterolateral cannula. The suture passer then penetrates the cuff and shuttles it out the anterior portal. Two limbs of sutures are hanging out the posterior portal and 2 are out the anterior portal. The marked pair

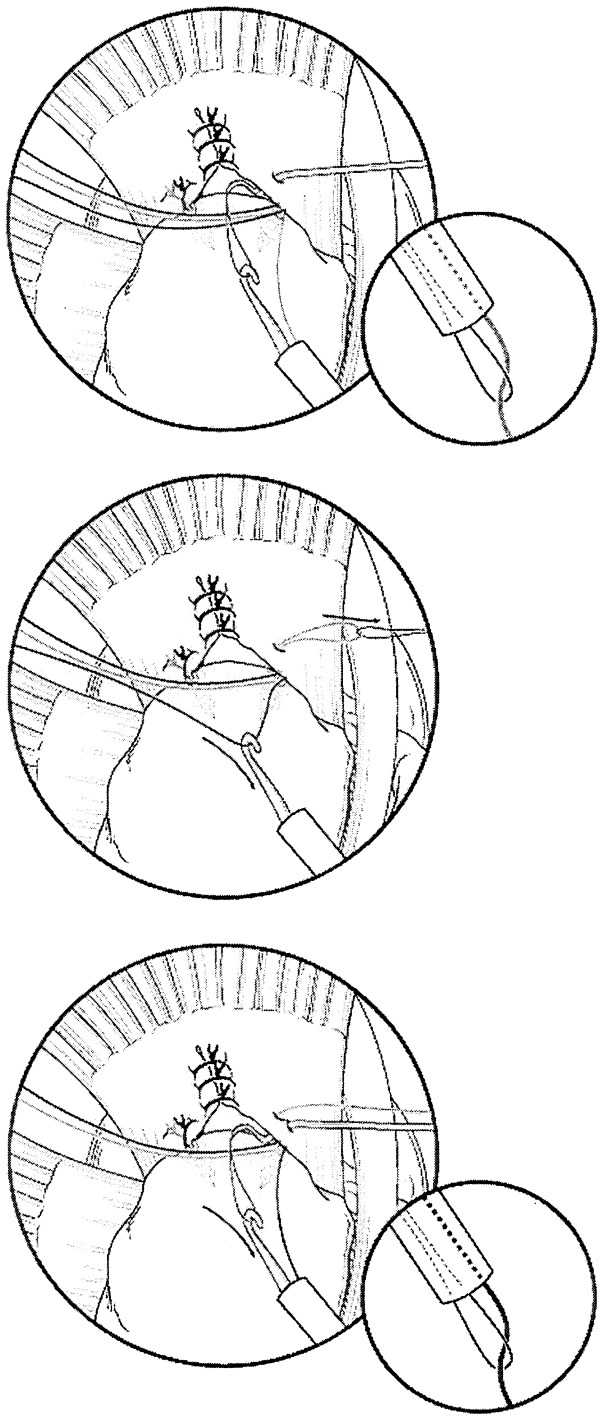

Fig 11. Anterior tendon leaf with suture passer from anterior portal.

are then retrieved out the anterolateral portal and tied. The same is done for the last pair (Fig 12).

Surgical Pearls

Optimal suture management is achieved by placing 1 anchor at a time, securing the tendon to the bone with both sutures before placing the next anchor, and using the accessory anterolateral portal as a dedicated knot tying portal. When passing or retrieving sutures, visualizing the anchor is helpful to monitor potential unloading of the suture anchor. Suture tying is always performed through cannulas, but suture-passing devices can be passed directly through skin portals. The arm is rotated so that the suture, anchor, and cannula are in alignment before tying a knot through the anterolateral cannula. Multiple alternating half hitches with alternating posts are used to secure the suture knot. Each throw includes pass pointing the suture limbs to maximize suture security. A minimum of 3 alternating half hitches with alternating post limbs is included with every knot after a slipknot or after 2 same-direction half hitches. Alternatively, a sliding knot is tied over the soft-tissue suture limb. As the knot slides into place, the tissue reduces to the tuberosity. Ideally, the knot should be placed over the tendon and not laterally over

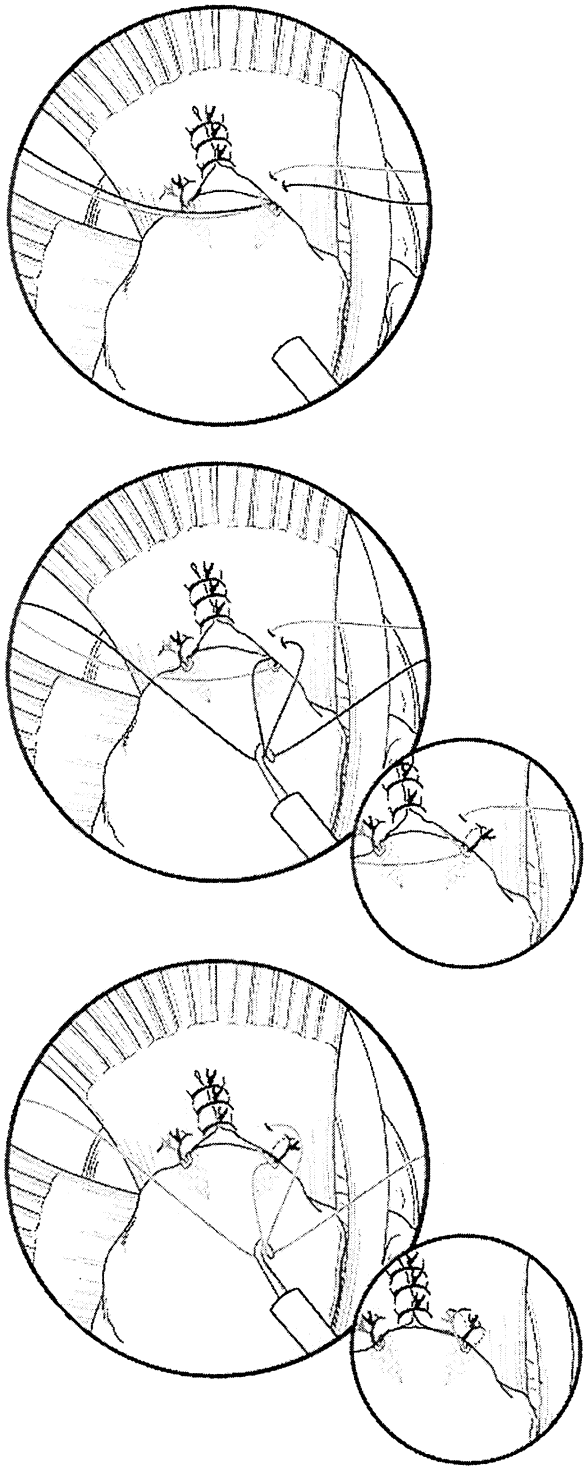

Fig 12. Securing of anterior tendon leaf.

the tuberosity. At the completion of the knot tying, sutures are cut 3-4 mm from the end of the knot. The arm is then rotated in order to dynamically assess the security of the repair. Different suture types can be placed in almost any type of anchor. There is no data at this time that suggests whether bioabsorbable or metal anchors are superior, but anchors that minimize suture trauma are preferred.

REHABILITATION

Arthroscopic repair of a torn rotator-cuff tendon does not shorten the time required for biologic healing; therefore, postoperative protection is similar to open rotator-cuff repair. The rehabilitation protocol is guided by several factors, including the size of the tendon tear, chronicity of the tear, the quality of the repair, the surgeon's assessment of repair tension, the tear location, and the patient's specific factors, such as chronic medical conditions.[15] Overall, the phases of rehabilitation protocol follow these guidelines:

Phase 1 (0-6 weeks): Protection of repair tendon. Abduction pillow and sling worn continuously except for hygiene and exercise. Passive range of motion with specific limits. Active assisted range of motion for small tears with good-quality tissue. Additional closed-chain scapular protraction/retraction.

Phase 2 (6-12 weeks): Progress to full passive motion. Begin active assistive and active motion. Advanced to light strengthening for small tears with good-quality tissue. Advance strengthening of intact cuff. Light strengthening of scapular stabilizers.

Phase 3 (12-16 weeks): Passive stretching and end ranges of motion. Advanced strengthening of repaired cuff. Progressive strengthening of scapular stabilizers.

Phase 4: Functional strengthening, progressive resistive exercises, proprioception, re-education, sports specific rehabilitation.

CONCLUSION

The results of arthroscopic rotator-cuff repairs performed by advanced shoulder arthroscopists are equal to the results of open rotator-cuff repair.[16-18] The ability to achieve results similar to those achieved during open repairs with reduced morbidity is appealing. Although pain relief and range of motion may be improved even without lasting cuff integrity, the long-term functional result is clearly related to an intact cuff repair.

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